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A SUMMARY OF STUDIES OF FISH POPULATIONS IN INDIAN CREEK, PLUMAS COUNTY, 1977-1990

by

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INTRODUCTION

In 1976, the Department of Water Resources (DWR) initiated an instream flow program to identify streams that would benefit from flow enhancement to assess instream values and identify trade-offs required to enhance these streams. The Northern District of DWR selected Indian Creek below Antelope Reservoir in Plumas County (Figure 1) as one of the streams to study under this program. Initial flow studies by DWR indicated that flow augmentation could double trout habitat in the first 16 km of Indian Creek (Appendix 1) below the dam and increase habitat by 25 percent in lower reaches (DWR 1979). As a result of this study, DWR and the Department of Fish and Game (DFG) decided to operate Antelope Reservoir to increase flow releases from 0.14 cms to 0.57 cms year-round on a trial basis.

Previous studies on Indian Creek have documented pre-project fish abundance (Gerstung 1973), recreation use including fishing effort and catch (Brown 1990), instream flow values (Hinton and Haines 1981), and water quality (Boles 1980). The current fisheries study was conducted from 1977 through 1990 to provide information on trout age, abundance, and growth to be used to evaluate effects of the operation of Antelope Reservoir on trout in Indian Creek (Brown 1978, Brown and Haines 1979, Haines and Brown 1980, Villa and Brown 1981, Villa 1982, Bumpass and Brown 1989, Bumpass and Smith 1989,

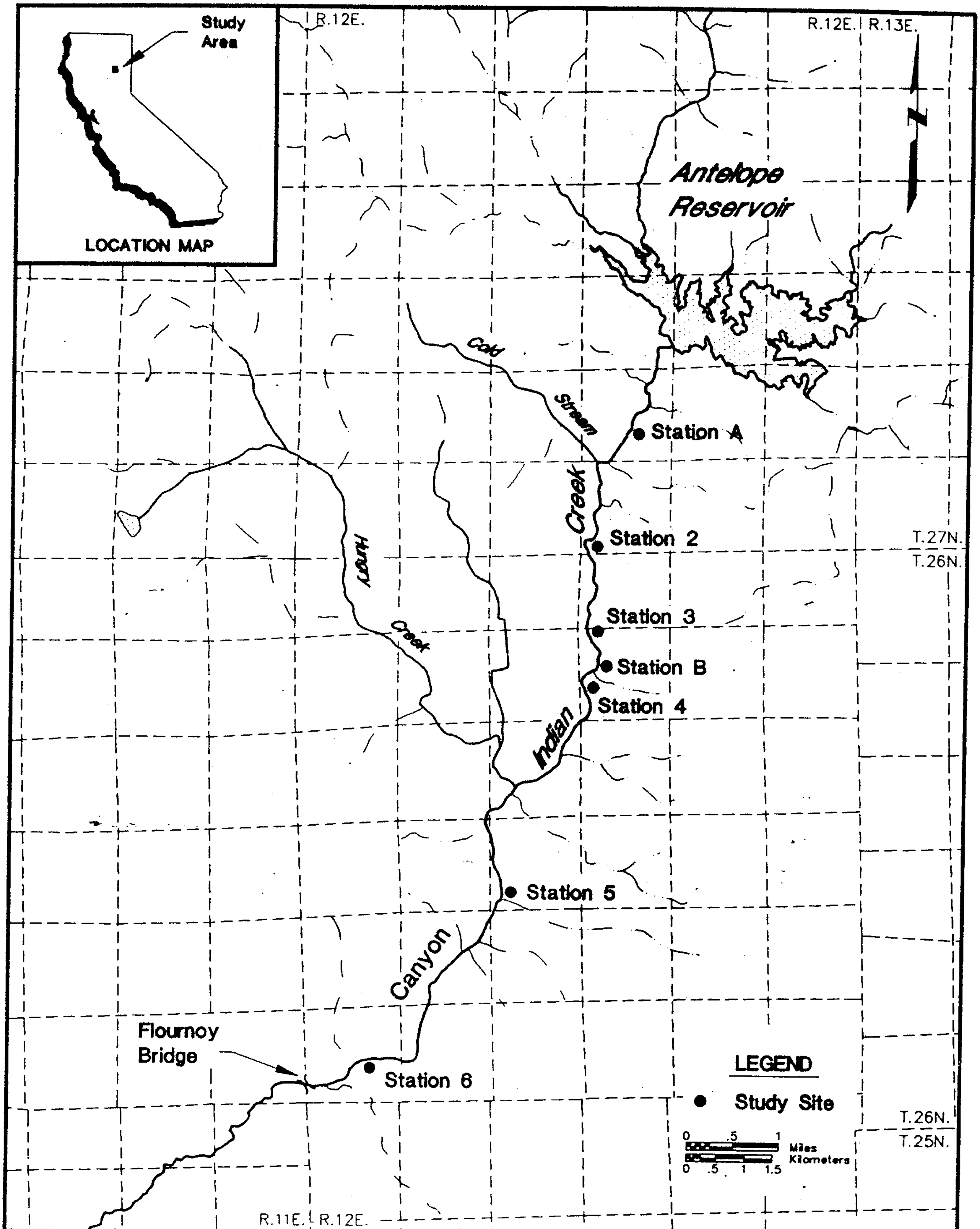

Figure 1. Stations sampled to determine standing crop of fishes in Indian Creek, Plumas County, 1977-1990.

Bumpass et al. 1987a, Bumpass et al. 1987b, Brown 1991).

The purpose of this report is to summarize studies of fish populations in Indian Creek, evaluate methods used in studies from 1977 through 1990, correlate the effects of environmental variables such as flow, water quality, and cattle grazing with populations of trout, and identify future study needs.

STUDY AREA

The Indian Creek study area extends from the stream at the base of Antelope Dam to Flournoy Bridge (Figure 1). The stream flows through rocky canyons and grassy meadows. Elevation in the study area is 1464 m. Steep hillsides surrounding the stream are covered with pine, cedar, and fir trees. Trees that border the stream are predominantly alder. Indian Creek averages 7m in width in the study area.

Stream flow is a combination of releases from Antelope Dam and inflow from tributaries such as Cold Stream and Hungry Creek. Storms and snow melt can raise flows to flood levels in February, March, April, or May. Significant flooding occurred in 1982, 1983, and 1986. Summer flow is largely comprised of releases from the dam. Flow is 0.14 cms in very dry years, 0.28 cms in dry years, and 0.57 cms in normal or wet years (Hinton and Haines 1981).

Water quality and benthic organisms were sampled in six stations in 1979 in the study area by personnel from the Water Quality and Biology Unit of the Northern District of DWR. Dissolved oxygen averaged 9.8 ppm while Ph averaged 7.3. Alkalinity was 44 mg\L as $CaCO_3$ while turbidity averaged 1.2 FTU. Dominant benthic macroinvertebrates were mayflies of the genus Baetis, stoneflies of the genus Hydropsyche, and flies of the subfamily Chironominae and genus Simulium (Boles 1980).

NAMES OF FISHES

The following species of fishes were caught in this study: rainbow trout (Oncorhynchus mykiss), brown trout (Salmo trutta), brown bullhead (Ictalurus nebulosus), golden shiner (Notemigonus crysoleucas), speckled dace (Rhinichthys osculus), hardhead (Mylopharadon conocephalus), Sacramento squawfish (Ptychocheilus grandis), Lahontan redside (Richardsonius egregius), Sacramento sucker (Catostomus occidentalis), and green sunfish (Lepomis cyanellus).

METHODS

Physical Measurements

Standing stocks of fishes were estimated at from four to seven stations in Indian Creek (Figure 1). Stations were intentionally selected to be near stations sampled in previous DFG studies (Gerstung 1973). Markers had previously been placed in trees along the stream to identify station boundaries. Stations varied in length from 25.3 to 90 m. The length, width of each station was measured with metric tape measures. The depth of water was determined by measuring water depth at the center of five equally spaced intervals across five transects at each station.

Biological Measurements

Fish were captured with a battery-powered backpack electroshocker in stream sections blocked by seines as described by Platts et al. (1983). Captured fish were removed from the net-enclosed section on each pass. Standing stock estimates were developed using the two-count method of Seber and LeCren (1967) or the multiple-pass method of Leslie and Davis (1939) with limits of confidence computed using a formula proposed by DeLury (1951).

The weights of trout and nongame fishes were measured by displacement. Fork length (FL) of each fish caught was measured to the nearest millimeter.

Scale samples were taken from brown trout and rainbow trout over 100 mm in length. Scales were taken just above the lateral line between the dorsal and adipose fin (Scarnecchia 1979) and placed in a piece of paper inserted in a small coin envelope (Drummond 1966). Scales were mounted dry between microscope slides, and their images were projected on a NCR microfiche reader at a magnification of 42x. Scale measurements for the calculation of growth were recorded to the nearest millimeter along the anterior radius of the anterior-posterior axis of the scale. Estimation of instantaneous population growth rate was calculated (Ricker 1975) with significant values of correlation coefficients taken from a table (Steel and Torrie 1960).

Instantaneous population growth rate = $b(\log_e l_2 - \log_e l_1)$

b = between ages functional slope
l_1 = initial length for the last complete year of growth
l_2 = final length for the last complete year of growth

Standing crops of brown trout and rainbow trout were calculated for individual stations where each species was caught and then combined for the entire creek. Age and growth was calculated for the population (Everhart et al. 1975). Length-weight relationships were determined for both brown trout and rainbow trout (Lagler 1956). The coefficient of condition and 95 percent confidence intervals were calculated for all trout (Carlander 1969).

RESULTS AND DISCUSSION

Fish Population Estimates

Population and biomass estimates were made for brown and rainbow trout in Indian Creek from 1977 through 1990 (Table 1). Brown trout were usually the dominant species. Their abundance peaked in 1988 with 6676 trout\ha, however biomass was greatest (60.0 kg\ha) in 1980. Brown trout averaged 47.2 kg\ha and 2050 trout\km. Rainbow trout were also consistently abundant. Rainbow trout averaged 16.1 kg\ha and 232 trout\km over eleven years of sampling on Indian Creek. More rainbow trout were caught in 1980 (702 trout\ha and 44 kg\ha biomass). All trout averaged 63.3 kg\ha and 2,282 trout\km (Table 1). The presence of two sympatric species such as rainbow trout and brown trout in Indian Creek can result in greater exploitation of resources resulting in higher than expected production (Chapman 1978).

Gerstung (1973) recorded data from 278 streams in the northern Sierra Nevada mountains. Trout biomass averaged 45.9 kg\ha. Fifty stations were sampled in the Owens River, in the southern Sierra Nevada (Deinstadt et al. 1985, Deinstadt et al. 1986). Brown trout standing crop averaged 105.9 kg\ha and 3,038 trout\km. Rainbow trout averaged 30.2 kg\ha and 1,620 trout\km. Platts and McHenery (1988) reported that brown trout\rainbow trout combinations averaged 500 trout\ha and 61 kg\ha in the Rocky Mountain Forest ecoregion, and 4,100 trout\ha and 87 kg\ha in the Sierra Forest ecoregion.

Table 1. Population estimates and biomass of rainbow and brown trout in Indian Creek, 1977-1990.

	Rainbow Trout		Brown Trout	
Date	Biomass (kg\ha)	Population Estimate (no\ha)	Biomass (kg\ha)	Population Estimate (no\ha)
1977	12.0	82	58.0	1642
1978	7.0	137	58.0	694
1979	20.0	187	43.0	4160
1980	44.0	702	60.0	1627
1981	14.0	126	45.1	1905
1982	12.5	450	46.0	904
1986	11.0	320	15.0	320
1987	21.0	115	39.0	1846
1988	6.0	108	56.0	6676
1989	9.0	91	57.0	1150
1990	20.2	240	42.0	1627
Mean	16.1	233	47.2	1879

Estimates of population and biomass were made for seven species of non-salmonid fishes in Indian Creek (Table 2). The most golden shiners were caught in 1977 with 290 shiners\ha, but biomass was greatest in 1980 at 13.8 kg\ha. Speckled dace were only caught in 1977. Their abundance was 140 dace\ha and biomass was 1.7 kg\ha. Sacramento squawfish were only caught in station six (Figure 1). They were equally abundant in 1979 and 1980 at 50 squawfish\ha, but biomass was largest (1.1 kg\ha) in 1979. Lahontan redside were only caught from 1978 through 1982. They were most abundant in 1982 (90 redsides\ha). Biomass was also greatest in 1982 (0.1 kg\ha). Abundance of Sacramento suckers varied throughout the study period. They appeared in greatest numbers and biomass in 1978 (480 suckers\ha and 6.0 kg\ha). Green sunfish appeared in the catch in 1982.

Sunfish population was estimated to be 110 sunfish\ha and biomass was 0.3 kg\ha. Brown bullhead appeared in the catch from 1977 through 1982, but none was caught after 1982. The most and heaviest bullheads were caught in 1977. Their abundance was 1770 bullheads\ha and biomass was 143 kg\ha (Table 2).

The distribution and abundance of fish in Indian Creek is largely a function of stream flow. Species such as golden shiners, speckled dace, Lahontan redside, green sunfish, and brown bullhead pass over the spillway of Antelope Dam in years when enough runoff is available to fill Antelope Lake to overflowing. During dry years they are rarely found in the creek. No member of these species has been caught in Indian Creek since 1986 (Table 2), although creel census in 1992 shows that brown bullheads are still present in the lake (R. Hinton, DWR, personal communication).

TABLE 2. Estimated numbers (fish\ha) and biomass (kg\ha) of non-salmonid fishes in Indian Creek, 1977-1990. Biomass is in parenthesis.

Year	Brown Bullhead	Golden Shriner	Speckled Dace	Sacramento Squawfish	Lahontan Redside	Sacramnto Sucker	Green Sunfish
1977	1770 (143)	287 (1.0)	131 (1.7)	25 (0.3)	0	189 (5.4)	0
1978	83 (36)	5 (0.1)	0	5 (0.1)	10 (0.1)	480 (6.0)	0
1979	0	0	0	46 (0.2)	0	116 (0.9)	0
1980	1183 (65.9)	219 (6.4)	0	46 (0.5)	5 (0.1)	25 (3.3)	0
1981	31 (3.3)	5 (0.1)	0	0	0	5 (0.8)	0
1982	311 (26.8)	140 (2.9)	0	5 (0.1)	92 (0.5)	117 (2.3)	110 (0.3)
1986	0	0	0	32 0.4	0	248 (5.6)	0
1987	0	0	0	37 (0.3)	0	12 (0.1)	0
1988	0	0	0	0	0	40 (3.9)	0
1989	0	0	0	0	0	0	0
1990	0	0	0	8 (0.2)	0	16 (0.5)	0

Age Composition of Trout

One thousand four hundred and sixty-seven brown trout scales were read for age determination. The average calculated length of 1,467 brown trout at age I was 98 mm fork length (FL). The average calculated lengths of 526 trout at age II was 193 mm. The average calculated lengths of 88 trout at age III was 285 mm and 12 trout were estimated to be 384 mm at age IV (Table 3). Brown trout from Indian Creek are significantly larger at ages II and III than the average of brown trout from west slope Sierra Nevada streams from free-flowing streams and streams below dams of similar habitat sampled by DFG (Snider and Linden 1981). Brown trout from this area were 105 mm FL at age I, but only 163 mm at age II and 210 mm at age III. Lengths of age IV trout were not reported. Brown trout from Indian Creek are more typical in size at each age class to trout from streams that flow down the east slope of the Sierra Nevada mountains. Brown trout from the east slope were 108 mm FL at age I, 215 mm at age II and 314 mm at age III. Lengths of age IV trout were not reported. Larger trout in Indian Creek could be a result of prolonged releases through summer and fall of cool water from Antelope Reservoir.

TABLE 3. Estimated length (mm fork length) of brown trout by age in Indian Creek.

Year	Number of Trout	Weighted Means of Length at Age			
		I	II	III	IV
1977	58	104			
1978	89	96	189	258	
1979	137	106	198	311	
1980	199	105	197	291	
1981	133	101	180	296	366
1982	265	100	196	290	372
1986	211	100	195	286	402
1987	69	107	204	286	
1988	105	75	179	244	
1989	125	85	207		
1990	76	90	174	265	
Weighted Mean		98	193	285	384
N		1467	526	88	12

Age 0+ brown trout made up 64 % of the total catch. Age I+ and II+ trout comprised 26 % and 9 % of all brown trout caught. Age III+ trout made up only 2 % of the catch. Few age III+ and IV+ trout have been caught by electrofishing in study areas (Brown 1978, Brown and Haines 1979, Haines and Brown 1980, Villa and Brown 1981, Villa 1982, Bumpass and Brown 1989, Bumpass and Smith 1989, Bumpass et al. 1987a, Bumpass et al. 1987b). Trout do live longer than 4 years in Indian Creek, but many are caught during the angling season (McFadden and Cooper 1962, R. Hinton DWR personal communication) and others occupy areas such as deep, brushy pools and deep crevasses between boulders that are difficult to electrofish with backpack shockers (Johnson 1965). Sampling outside of established study areas has produced trout in excess of 600 mm FL (Bumpass and Smith 1989).

Scales from 172 rainbow trout were examined in the course of these studies. The average calculated lengths of 172 rainbow trout at age I was 112 mm fork length (FL). The average calculated lengths of 28 trout at age II was 183 mm. The average calculated lengths of 5 trout at age III was 365 mm. (Table 4).

Most rainbow trout caught were age I+. Age 0+ and I+ trout made up 41% and 44% of the catch. Age II+ and III+ comprised 14% and 1% of the total catch (Brown 1978, Brown and Haines 1979, Haines and Brown 1980, Villa and Brown 1981, Villa 1982, Bumpass and Brown 1989, Bumpass and Smith 1989, Bumpass et al. 1987a, Bumpass et al. 1987b).

TABLE 4. Estimated length (mm fork length) by age of rainbow trout in Indian Creek.

Year	Number of Trout	Weighted Means of Length at Age		
		I	II	III
1982	47	115	189	8
1986	57	129	209	402
1987	34	115	230	328
1988	8	100	165	
1989	10	85	161	
1990	16	71	159	
Weighted Mean		112	183	365
N		172	28	5

Growth of Trout

Instantaneous population growth rate for brown trout was variable over the years Indian Creek was sampled. Instantaneous population growth rate of age I-II trout was slowest in 1979 and highest a decade later in 1989. Instantaneous population growth rate averaged 2.084 g. Age II-III brown trout grew more slowly than age I-II trout. Growth of trout of this age was greatest in 1990 and slowest in 1988. Instantaneous population growth rate of age II-III brown trout averaged 0.919 g (Table 5).

TABLE 5. Estimates of instantaneous population growth rate (g) of brown trout and rainbow trout in Indian Creek.

	Brown Trout		Rainbow Trout	
	Age Interval			
Year	I-II	II-III	I-II	II-III
1978	2.214	0.938		
1979	1.394	1.670		
1980	2.086	1.219		
1981	1.850	1.505		
1982	2.029	-	1.541	
1986	1.777	0.965	1.242	1.151
1987	1.974	1.012	2.080	1.070
1988	2.616	0.605	1.329	
1989	2.288	-	1.856	
1990	2.154	1.776	2.379	
Mean	2.084	0.919	1.738	1.111

Instantaneous population growth rate was estimated from 1982 through 1990 for age I-II rainbow trout. Highest values were recorded in 1990 and lowest growth was recorded in 1986. Average instantaneous population growth rate was 1.738 g. Age II-III rainbow trout grew at an average instantaneous population growth rate of 1.111 g for the years 1986 and 1987 (Table 5).

Most growth of trout in Indian Creek takes place from April to late June. Growth in negligible from December through March. Trout reach their peak condition in June and their lowest values in fall and winter (Beyerle and Cooper 1960). Growth is controlled by elements of habitat such as stream flow including flooding (Waters 1983, Hansen and Waters 1974, Wesche et al. 1987) water quality such as water temperature (Jowett 1992), conductivity, hardness, and alkalinity (Scarnecchia and Bergersen 1987, Waters et al. 1990), physical components of habitat such as substrate diversity (Scarnecchia and Bergersen 1987), water velocity and undercut banks (Oswood and Barber 1982), deep pools with extensive cover (Lewis 1969), boulders and woody debris (Mesick 1988), and siltation (Waters 1983). Growth is also controlled by the presence of other species (Chapman 1978), stream biota as invertebrate biomass (Jowett 1992), and fishing pressure (Wesche et al. 1987).

Correlation Between Stream Flow and Trout Abundance and Growth

The abundance of young brown and rainbow trout in Indian Creek is significantly ($P<0.05$) correlated with spring floods (Table 6). Spring floods devastated age 0 trout in

Indian Creek in 1982 and 1986 based on population sampling the following September. High flows in April and May 1982 and March in 1986 destroyed redds, killing eggs, and washing newly emerged trout out of the study area. Spring floods can decimate eggs and young of fall spawning trout (Seegrist and Gard 1972, Hansen and Waters 1974, Harvey 1987). Young-of-the-year trout are more strongly affected by floods than adults because of their limited swimming ability and small size. Young of the year rainbow trout are also negetatively affected by spring floods (Pearsons et al. 1992). Floods can result in the loss of two year classes due to destruction of eggs and fry and mortality of older trout due to loss of habitat (Hansen and Waters 1974). Physical factors such as suitable space and cover are more important in small streams than in larger rivers. Floods in small streams such as Indian Creek are catastrophic to stream biota and may reduce productive capacity of a stream for extended periods. Floods may reduce useable habitat by filling pools with sand and debris and blanketing riffles with sand.

TABLE 6. Correlations among stream flow and fish population statistics.

x_1 = brown trout population in numbers\ha (no\ha)
x_2 = age 0 brown trout population in no\ha
x_3 = catchable brown trout (127 mm FL and larger) population in no\ha
x_4 = rainbow trout population in numbers\ha
x_5 = age 0 rainbow trout population in no\ha
x_6 = catchable rainbow trout population in no\ha
x_7 = total trout population in no\ha
x_8 = brown trout biomass in kg\ha
x_9 = rainbow trout biomass in kg\ha
x_{10} = total trout biomass in k\ha
x_{11} = condition of trout
x_{12} = growth of brown trout
x_{13} = growth of rainbow trout
x_{14} = summer stream flow in cubic meters per second (cms)
x_{15} = peak spring stream flow in cms

Correlation	Degrees of Freedom	Coefficient of Correlation	Probability
$r_{1.14}$	9	-0.75	<0.01
$r_{2.14}$	9	-0.71	<0.05
$r_{3.14}$	13	0.73	<0.01
$r_{4.14}$	9	0.56	>0.05
$r_{5.14}$	13	0.83	<0.01
$r_{6.14}$	13	0.83	<0.01
$r_{7.14}$	9	-0.71	<0.05
$r_{8.14}$	13	0.69	<0.01
$r_{9.14}$	13	0.57	<0.05
$r_{10.14}$	11	0.64	<0.05
$r_{11.14}$	9	0.12	>0.05
$r_{12.14}$	9	0.41	>0.05
$r_{13.14}$	9	0.57	>0.05
$r_{2.15}$	9	-0.64	<0.05
$r_{5.15}$	9	0.61	<0.05

Sustained stream flow through the summer as a result of releases from Antelope Dam has resulted in trout populations that are much larger than during the preproject period. Trout averaged 14 per ha in three years (1962-1964) of data collected prior to construction of Antelope Dam. Brown trout comprised 9 per ha and rainbow trout made up 5 per ha (Gerstung 1973 and DFG file data). Populations increased after the dam was built. Rainbow trout averaged 233 per ha in eleven years of sampling and brown trout averaged 2,050 per ha (Table 1). Streams with the higher base flows present for the longest duration during the summer support higher standing stocks of brown trout (Wesche et al. 1987). Increasing summer flow in Indian Creek produced more useable area for trout (Hinton and Haines 1981) which may have increased trout abundance (Jowett 1992).

The contention that summer flow and trout numbers are related in Indian Creek (Hinton and Haines 1981) is largely true. The relationship between summer flow and brown trout populations is highly significant ($p < 0.01$), while the relationship between flow and population of all trout is significant ($p < 0.05$). Summer flow is not significantly related to rainbow trout populations ($p > 0.05$), but future sampling could strengthen this correlation. Catchable-sized trout greatly benefit from higher summer flows. The correlations between flow and catchable brown and rainbow trout are significant ($p < 0.01$)(Figure 2). The relationship between flow and brown trout biomass is highly significant ($p < 0.01$) while the same relationship for rainbow trout is significant ($p < 0.05$). Flow and total trout biomass are also significantly related ($p < 0.05$) (Figure 3).

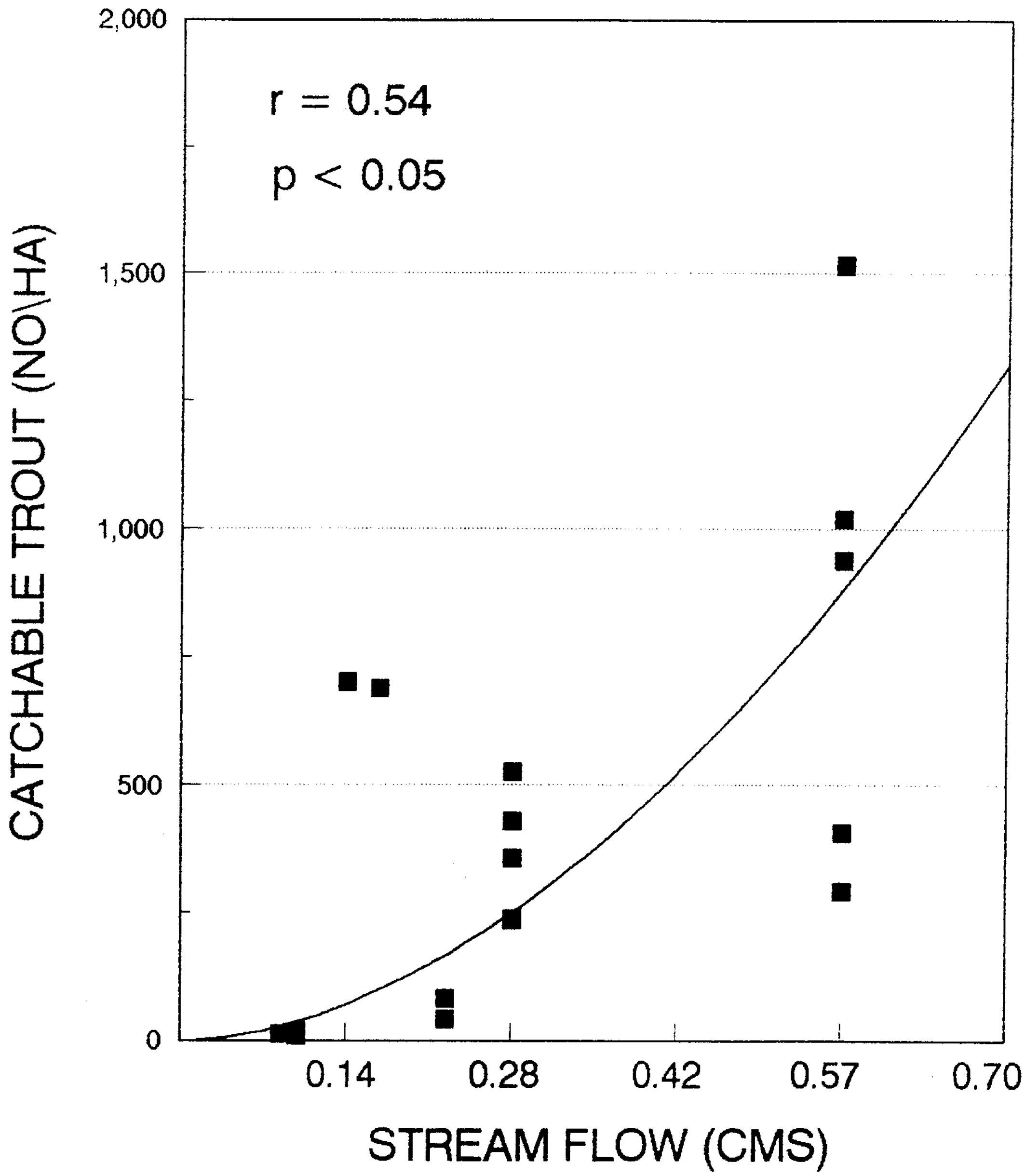

FIGURE 2. The relationship between stream flow and catchable trout in Indian Creek.

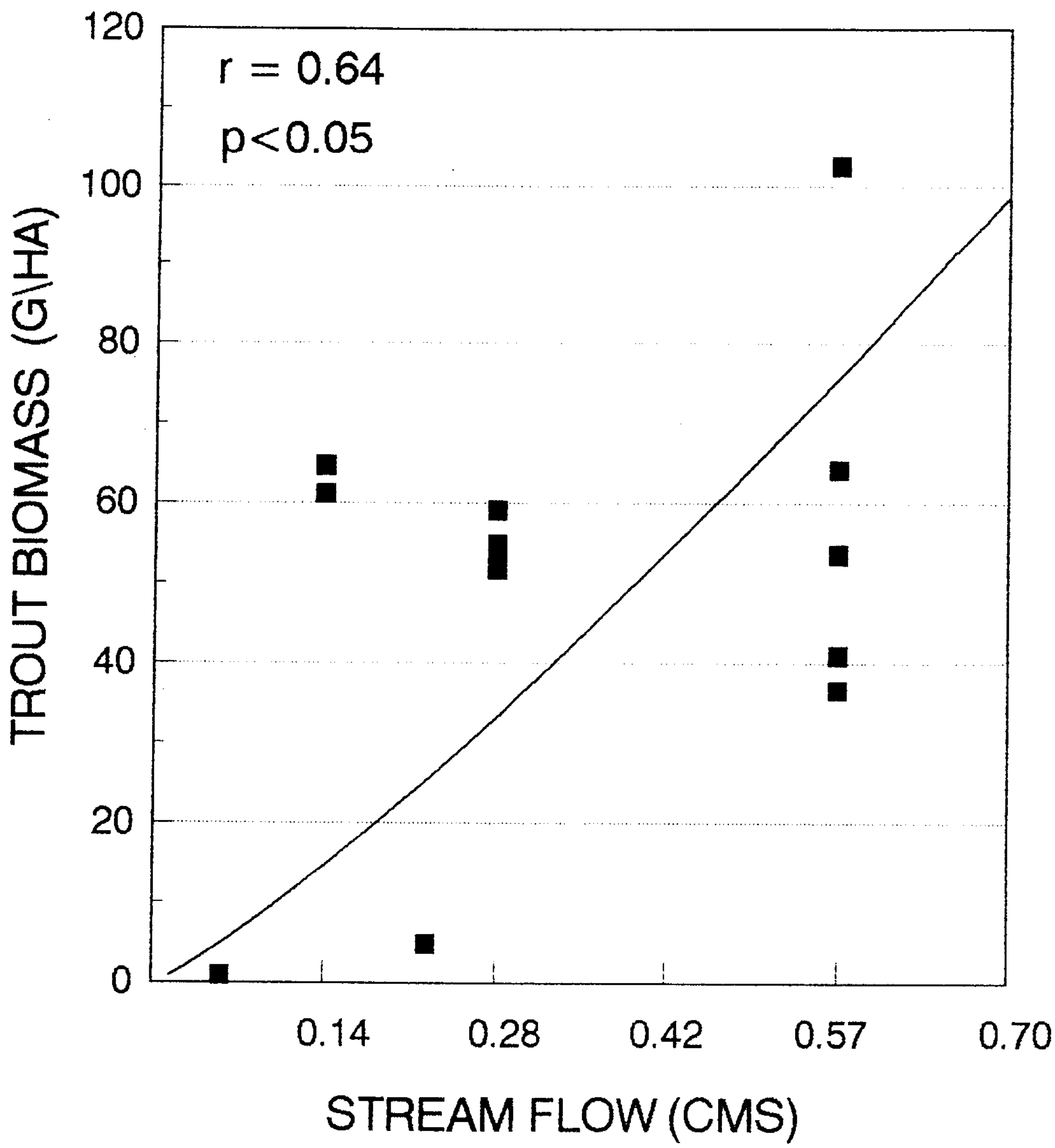

FIGURE 3. The relationship between stream flow and trout biomass in Indian Creek.

Young brown trout favor low flow conditions. Numbers of age 0 brown trout are negetatively correlated with flow ($r = -0.71$, $p < 0.05$), however, the relationship between flow and age 0 rainbow trout is positive and highly significant ($p < 0.01$). Spring flow can determine abundance of young trout in Indian Creek. Brown trout spawn in fall and their eggs hatch in late winter and spring (Moyle 1976). High flows in spring shift gravel destroying eggs and larvae and sweep recently emerged trout downstream (Hansen and Waters 1974, Harvey 1987, Elwood and Waters 1969, Seegrist and Gard 1972). In contrast, abundance of age 0 rainbow trout is positively correlated to spring flow and is significant ($p < 0.05$). Rainbow trout spawn in the spring (Moyle 1976). Higher flows in the spring provide more spawning habitat (Hinton and Haines 1981) and rainbow trout eggs are left to develop on a falling hydrograph. Therefore, rainbow trout populations can increase following high flow in winter or early spring (Hansen and Waters 1974, Seegrist and Gard 1972).

Growth rates of trout can be reduced the summer following a flood as a result of habitat degradation and reduction of invertebrate food supplies (Elwood and Waters 1969, Hansen and Waters 1974). Growth rates for age I-II brown and rainbow trout were well below average following 1986 - the largest flood in Indian Creek in the period of study. However, growth rates for age II-III trout were above average (Table 5). Floods reduce growth rates by degrading pool and riffle habitat by covering areas with fine material and reducing invertebrate food supplies (Waters 1983, Elwood and Waters 1969). Although no significant relationship was found between stream flow and growth of brown and rainbow trout relatively high coefficients of correlation suggest that additional observations may help establish significance. Growth in Indian Creek could be related to flow because increased flows increase useable habitat for food production and cover (Hinton and Haines 1981), two elements that influence productivity, standing crops, and growth (Saunders and Smith 1963, Lewis 1969, Mesick 1968, Wesche et al. 1987, Jowett 1992).

Alkalinity is an element of habitat that is directly related to production and biomass of trout (Scarnecchia and Bergersen 1987). Soft water (83 mg\L as $CaCO_3$) is characteristic of low productivity streams. Higher productivity is more typical of hard water streams (200-250 mg\L as $CaCO_3$) (Waters et al. 1990). The alkalinity of the water in Indian Creek was measured at 44 mg\L as $CaCO_3$ (Boles 1980). Indian Creek is not as highly productive as alkaline streams like Fall River, Hat Creek, or Hot Creek, but is more typical of most lower alkalinity streams in the Sierra Nevada Mountains. More data on water quality should be collected at different stream flow to correlate trout abundance with elements of water quality.

Cattle grazing in and along streams such as Indian Creek can cause reductions in trout populations (Platts and Nelson 1988). Cattle can frequently be seen grazing in meadows through which Indian Creek flows. They climb up and down banks and walk along and through the creek. Cattle break down stream banks causing erosion and loss of stream side trees and shrubs that cool stream temperatures and provide cover for trout (Rinne 1988). Streamside grazing also degrades water quality. Fencing has increased trout populations 2-5 times within 3-5 years after grazing stops. Riparian vegetation can quickly regain its vegetative productivity (Platts and Wagstaff 1984).

Evaluation of Methods

Methods and procedures used in sampling to estimate trout populations can injure fish and produce errant estimates. Fish were captured in Indian Creek by electrofishing. Population estimates were made by the removal method. Electrofishing can injure or kill trout through spinal injuries (Sharber and Carothers 1988). Electrofishing may also lead to underestimating trout populations if passes follow each other in rapid (less than one hour) succession (Peterson and Cederholm 1984) or if habitat is complex in terms of cover and pool surface (Boccardy and Cooper 1963, Rodgers et al. 1992). Populations may also be underestimated if sampling effort is not uniform on consecutive passes or if some size trout are less vulnerable to capture by electrofishing (Johnson 1965). Uniform effort can be better exerted by carefully electrofishing on subsequent passes rather than depending on the time electric current is flowing (Riley and Fausch 1992).

Future Studies

Future studies should include at least three electrofishing passes at each sampling station (Riley and Fausch 1992) with a pause of at least one hour between each pass to avoid underestimating populations (Peterson and Cederholm 1984). Water quality elements such as dissolved oxygen, total alkalinity, and turbidity should be measured at two stations in the study area during each period of sampling to help establish relationships between water quality variables and trout populations. Trout should be sampled in winter to determine true length at age. DFG should evaluate the impact of largemouth bass (Micropterus salmoides) on trout. Largemouth bass were introduced into Indian Creek in 1993 as a result of plants of this species into Antelope Lake in 1981 by the DFG to create a sport fishery and prolonged spill of water over Antelope Dam (R Hinton, DWR, personal communication).

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APPENDIX 1

Metric Conversion Factors

Quantity	Metric Units	Divide by	English Units
Length	millimeters (mm)	25.4	inches
	meters	0.3048	feet
Area	hectare (ha)	0.4047	acre
Weight	gram (g)	28.35	ounces
Flow	cubic meters per second (cms)	0.0283	cubic feet per second
Abundance	trout per hectare (trout/ha)	2.47	trout per acre
Biomass	kilograms per hectare (kg/ha)	0.184	pounds per acre

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